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Common Waterborne Diseases Due to Bacterial, Fungal and Heavy Metal Contamination of Waters: A Case Study from Nacharam Area of Hyderabad, India

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ABSTRACT: Nacharam and its surroundings, located inside the city of Hyderabad in Telangana State, India, is vulnerable to water-borne diseases; therefore, the present research works on concentrations of dissolved hexavalent chromium (57−263 μgL^{-1}), lead (34−65 μgL^{-1}), cadmium (2.3−22.4 μgL^{-1}), and nickel (from below detection limit to 6.5 μgL^{-1}) in different surface water and groundwater bodies of this area. Results indicate that with the exception of nickel, the majority of studied water bodies and aquifers of the area are contaminated, to variable degrees, with dissolved heavy metals. Also health-affecting bacterial and fungal colonies have been found in drinking water and groundwater bodies of the area. These findings collectively point at impending health threats to the residents of the area, thus this study has conducted a health survey, whose data indicate that about two third of the residents are affected by waterborne ailments, including hair fall, skin rashes, tooth decay, diarrhea, and joint pain. Hair fall is one of the major problems affecting about 40% of the area population. Other waterborne health-related issues are faced by relatively smaller numbers of residents (10% or less). Based on the results from this study, it is recommended not only to conduct periodic analyses of water samples used for drinking and other purposes, which would assist the government and local authorities in taking necessary steps to prevent groom and spread of microorganisms, but also to monitor other anthropogenic activities, potentially capable of contaminating water sources, .

Keywords: inorganic pollution, microorganism, H_2O, hair loss, skin rash

INTRODUCTION

Consuming contaminated water leads to a gradual build-up of large number of chemicals in the body. These chemicals may range from sodium fluoride (an active ingredient in rat poison), chlorine, and aluminum to some heavy metals like nickel, chromium, lead, and cadmium. Beyond permissible limits, all of them are hazardous in our bloodstream. Presence of heavy metals like lead and cadmium in water is not beneficial at all, rendering them definitely toxic (INSA, 2011). Furthermore, there are reported cases of bacterial and fungal contamination in drinking water in many places (e. g., Hageskal et al., 2006; Saati and Faidah, 2013; Padmini et al., 2013), putting human health in danger.

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In an earlier research, we analyzed the concentrations of some dissolved heavy metals, namely Ni, Cr (VI), Cd, and Pb, in various surface and groundwater bodies of greater Hyderabad as well as the adjoining Ranga Reddy Region in India (Das Sharma et al., 2015, 2016). We documented that with the exception of nickel, the majority of water bodies and aquifers are contaminated with heavy metals to variable degrees. In view of low geochemical baseline values for chromium, cadmium, and lead, it was inferred that the origin of heavy metal pollution was anthropogenic, mainly from industrial activities and indiscriminate dumping of wastes (Das Sharma et al., 2015, 2016). Heavy metal contamination of groundwater and soil samples in Nacharam was also documented by Venkateswara Rao et al. (2016), who also argued that high contamination of groundwater and soil with heavy metals could be from anthropogenic sources, since the country rock granite did not contain high concentrations of these heavy metals. According to the Central Ground Water Board report, presence of heavy metals like Fe, Mn, Cd, and Ni have been noticed beyond permissible limits in groundwater samples of Nacharam's industrial area. Foundries and fabrication industries are cited to be responsible for discharging effluents, containing heavy metal wastes (Gumma, 2013). Several other studies, conducted on water quality assessment of Nacharam, reveal that the samples from this study area fall under hard to very hard category (Udayalaxmi et al., 2010; Gumma, 2013; Bhupathi et al., 2014). In a recent study, conducted by the Institute of Preventive Medicine in Hyderabad, it has been reported that faecal coliform bacteria exist above permissible limits in drinking water of both Alwal and Nacharam areas (Garari, 2016).

All told, the present study has been conducted with regard to our previous results on heavy metal contamination (Das Sharma et al., 2015, 2016) together with the reported anomalous hydro-geochemical and microbiological characteristics of water samples from Nacharam and its adjacent areas (Udayalaxmi et al., 2010; Gumma, 2013; Bhupathi et al., 2014; Garari, 2016),. The results, here, concern the concentrations of dissolved heavy metals in surface and groundwater samples of Nacharam Area while identifying fungal species in water samples, from various areas, such as Indira Nagar, Errakunta, Ambedkar Nagar, and Erkala Basthi, located within this locality. Fig. 1 illustrates the map of the study area. One might notice that Ambedkar Nagar is not marked in the diagram, though Erkala Basthi (being within Ambedkar Nagar) is (Fig. 1). A health survey was also conducted in these areas.

The purpose of this study is, therefore, to evaluate the plausible connections between the hydro-geochemical as well as presently-accrued microbiological characteristics of water samples and health data from the area under study. In other words, this study aims firstly at assessing the water quality in terms of fungal and heavy metal contamination and, secondly at deciphering the extent of water-borne common diseases, affecting the citizens of the area as a result of their continuous consumption and use of contaminated water.

MATERIALS AND METHODS

Tap water, surface water, and groundwater samples (from bore well with an average water table depth of ~150±30 m) were collected. In order to determine heavy metals in surface and groundwater samples, polypropylene bottles (1 litre) were soaked in 5% HNO3 for 24 hours, thence to get rinsed a number of times with deionized water. Afterwards, the bottles were dried and the water samples were collected in duplicate in these bottles after filtration with Whatmann 40 filter papers. Of the two bottles, containing filtered water sample, one was acidified with 5 ml HNO3 while the other was not. These bottles were sealed properly before getting transferred to the laboratory. The pH of each sample was measured almost immediately within an hour at the laboratory, using non-acidified samples and for this purpose, a calibrated systronic pH-meter (Model 335) was utilized to measure the pH, which had undergone a double-point calibration by means of specific buffer tablets of 4.01 and 9.18.

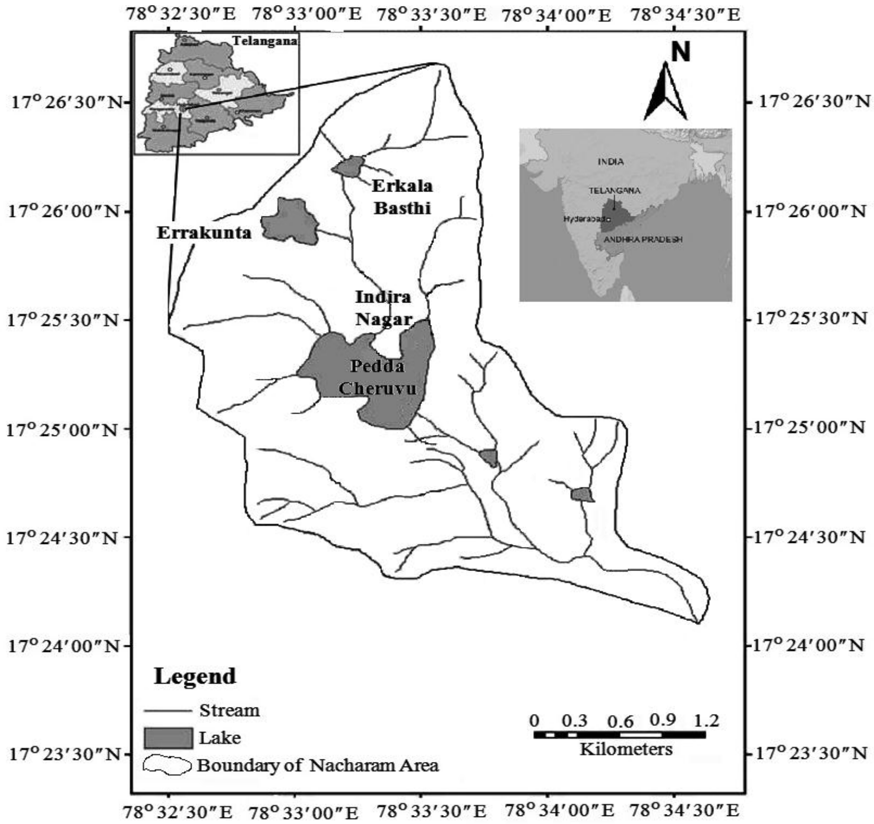

Fig. 1. Map of Telangana State, showing the boundaries of Nacharam area. The survey was conducted at Indira Nagar, Errakunta, and Ambedkar Nagar. Note that Erkala Basthi is marked in the figure, being located within Ambedkar Nagar.

We used a simple and low-cost analytical method to estimate heavy metals so that the instrument could be easily operated. The concentration of each metal in terms of absorbance was recorded by Elico–164 double beam spectrophotometer. In order to get maximum sensitivity of the spectrophotometer, the wavelength for maximum absorbance was chosen for calibration of each element's plot as well as subsequent sample analysis. Blends of suitable compounds have been identified through a number of trial runs so that each element of interest [i.e., Cr(VI), Cd, Pb, and Ni] would make strongly colored complexes, without much interference with other elements. If necessary, in some cases specific suppressor was also used to minimize the impact of unwanted ions. Since the intensity of the colored complexes depends on the concentration of the element of interest in a standard or sample solution, we have initially prepared standard calibration curves for each element. During their preparation, the light absorbance as a function of known concentration at a particular wavelength was plotted. The calibration curve for each element was generated between concentration and absorbance, subsequently used to evaluate dissolved heavy metal concentrations in natural water samples, collected from various sites (see also Supplementary File).

Also, abundance of the fungi in tap water and groundwater samples was determined. Water samples were filtered via filter papers and funnels to remove any dirt and macroscopic substance. Each water sample was collected in neatly-rinsed, clean, and dry sterile PVC bottles with a capacity of 200 ml. They were stored in a refrigerator until being examined individually for microbial analysis. Fungal abundance in each water sample was assessed, using serial dilution, streak plate, and pour plate method through Potato Dextrose Agar (PDA) medium, which was prepared from extracts of 200 gm of peeled potato tubers, 20 gm dextrose, and 15 gm agar in 1000 ml of distilled water. Afterwards, one ml of the water sample was added to the petri plate in both streak plate and pour plate methods, followed by 1 ml of the 4^{th} dilution (i.e., up to 1:10,000), added to the serial dilution. Each petri plate was incubated at 28 °C for seven days (Dubey and Maheshwari, 2006). Fungal colonies that developed were sub-cultured onto a fresh PDA medium to both isolate and identify the pure single colony.

As far as the health data from the area survey are concerned, there are numerous methods, adopted during a survey, to collect data of particular interest. These could involve (i) sending postal questionnaires, (ii) face-to-face interviews, (iii) telephone interviews, and (iv) web-based online responses from the respondents. Depending on the availability of resources such as budget, number of available research personnel, duration of the project, educational and financial background of the respondents, and the number of expected respondents in the survey, researchers usually adopt a suitable method. In the present study we preferred to conduct face-to-face interviews with the respondents, as this method often has the highest response rate. Furthermore, it has other advantages for the researchers. In this method the researchers (i) can make direct observations, (ii) generally do a better job of converting refusals in person, and (iii) can instill confidence in respondents by showing them official identification. Therefore it was decided to visit several households in Indira Nagar, Errakuntla, and Ambedkar Nagar, besides Erkala Basthi (which is within Ambedkar Nagar), located within Nacharam and its adjoining areas (Fig. 1). The questionnaires were designed with emphasis on more common water-borne diseases, and respondents were asked to answer them. Figure 2 shows some representative photographs, pertaining to such face-to-face interviews with the respondents. Altogether, 363 households were surveyed and answers to the questionnaires from each respondent of a house were noted down.

RESULTS AND DISCUSSION

Table-1 shows the range of Cr(VI), Cd, Pb, and Ni concentrations in samples, analyzed in this study. It includes the heavy metal data from the literature for the purpose of comparison, also mentioning the guideline values, recommended by the World Health Organization (WHO, 2004; 2011), as well as desirable limits, suggested by the Bureau of Indian Standard (BIS, 2012) for these heavy metals. What is more, it provides various health effects due to the presence of these heavy metals in excess. In case of chromium, the guideline/desirable value has been given for Cr (total), whereas we estimated Cr^{6+} in our collected samples. In this context, it may be noted that the two dissolved forms of chromium (Cr^{3+} and Cr^{6+}) can convert back and forth in water and human body, depending on the ambient environment. Therefore, the US Environmental Protection Agency (USEPA, 2013) suggested that the Cr (total), measured in a sample, should be treated as Cr^{6+}, the more toxic form of chromium.

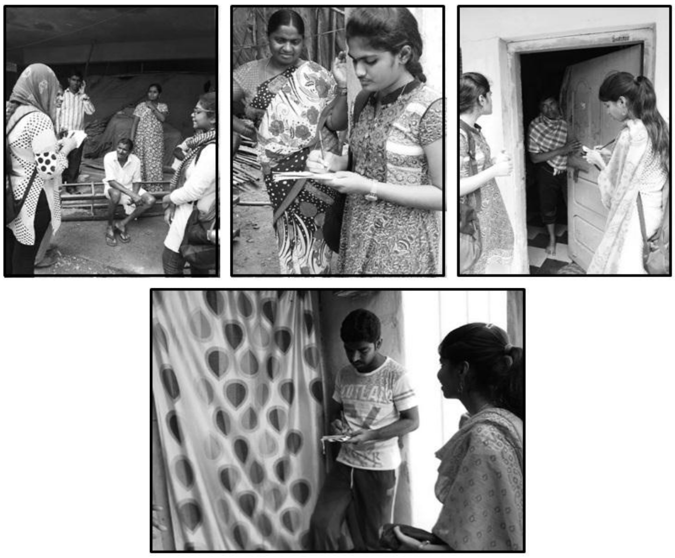

Fig. 2. Representative photographs of student researchers, conducting surveys at various households in Nacharam area.

Table 1. Major (literature data) and heavy metal contaminants (from both this study and the literature data) in water samples from Nacharam Area with their proven health effects

Inorganic contaminants in Nacharam groundwater	Reported above permissible limits in the study conducted by	Health effects with reference
	Inorganic	
Total Hardness (TH) = 700 mg/L Ca^{2+} = 222 mg/L	Gumma (2013)	Hardness of drinking water or its content of magnesium and calcium in some studies has indicated that there is a direct relation between TH and health problems such as risk for cardiovascular diseases, growth retardation, reproductive failure, etc. (Sengupta, 2013) However, some other studies indicate inverse relation between water hardness and cardiovascular diseases (e.g., Anderson et al., 1975; Smith and Crombie, 1987). Use of hard water may cause hair loss problems (cited in Srinivasan et al., 2013)
Total Hardness (TH) Range = 272—1408 mg/L Average = 714 mg/L Ca^{2+} Range = 28—390 mg/L Average = 138 mg/L Mg^{2+} Range = 25—385 mg/L Average = 163 mg/L	Bhoopathi et al. (2014)	
	Heavy metals	
Cadmium Range= 2.3—22.4 μg/L Average = 9.8 μg/L	This study	Irritation of the lungs and gastrointestinal tract, kidney damage, abnormalities of the skeletal system, and lung and prostate cancer (Bernard, 2008).
Cadmium Values not given	Gumma (2013)	
Chromium (VI) Range = 57—263 μg/L Average = 132 μg/L	This study	Allergic reactions, skin rash, nose irritations and nose bleed, ulsers, weakened immune system, genetic material alteration, kidney and liver damage, and cancer (Bielicka et al., 2005; Das and Singh, 2011).
Chromium (total) Range = 2—24 μg/L Average = 6 μg/L	Venkateswara Rao et al. (2016)	
Lead Range = 34—65 μg/L Average = 48 μg/L	This study	May result in toxic biochemical effects in humans, causing problems in the synthesis of haemoglobin along with effects on the kidneys, teeth, bone, gastrointestinal tract, joints and reproductive system. May cause acute damage to the nervous system (Skerfving and Bergdahi, 2007; Link, 2012).
Lead Range = 37-91 μg/L	Govil et al. (1999)	
Nickel Range = 0—6.5 μg/L Average = 2.3 μg/L	This study	Nickel allergy in the form of contact dermatitis, lung fibrosis, cardiovascular and kidney diseases, and cancer of the respiratory tract (Duda-Chodak and Blaszczyk, 2008).
Values not given	Gumma (2013)	

Guideline values recommended by WHO (2004; 2011) are: TH= 100 mg/L, Ca= 75 mg/L, Mg= 50 mg/L, Cd= 3 μg/L, Cr (total)= 50 μg/L, Pb= 10 μg/L, Ni= 70 μg/L.
Acceptable limits suggested by BIS (2012) are: TH= 200 mg/L, Ca= 75 mg/L, Mg= 30 mg/L, Cd= 3 μg/L, Cr (total)= 50 μg/L, Pb= 10 μg/L, Ni= 20 μg/L.

The high levels of Cr(VI), documented in the surface and groundwater bodies of Nacharam area might be originated from different industries in and around the study area, such as textile, engineering products, plastic and rubber, steel and other metal products, electrical machineries, communication equipment, printing and paint industries, tanneries and leather products, food processing, dyeing of saris and dress materials, bangle and ceramic industries, etc. (Ministry of MSME, 2014).

Cd concentration in the samples is characterized by highly variable values (Table-1). Various anthropogenic sources could be responsible for contamination of the natural water bodies, considered in this study. For example, Cd is widely used in steel industry, batteries and plastics, waste waters, fertilizers, e-waste, etc. (Bernard, 2008) Being very common in our study area (Ministry of MSME, 2014), these sources were the major contributors of cadmium into the environmental samples.

Table 1 shows the concentration of Pb, showing its highly variable range. One of the major problems, associated with Pb, is that it is an element whose legacy due to contamination gets imprinted as higher concentrations of lead in the environment, never to degrade (Davies, 1983). Therefore the variable range, observed here, reflects the contamination originating from different point sources. There is a huge number of anthropogenic sources of lead, including tetra alkyl lead in gasoline, lead arsenate as fungicides, plasters, paints, motor vehicles and other transportation equipment, house dusts, waste water, etc. (Link, 2012) The solubility of lead compounds in water is a function of several parameters such as the pH, hardness, salinity, and the presence of humic material (Link, 2012). As stated above, lead is an element that cannot be destroyed; therefore, high content of this element in water samples could be attributed to different kinds of anthropogenic activities, polluting the surface and groundwater bodies in various locations.

Ni concentration in the study area shows small variations, with its maximum value just being ~6.5 μgL^{-1}, which is significantly lower than the guideline value for drinking water, recommended by the WHO (2004), as well as the acceptable limit, set by BIS (2012). Thus all water bodies, considered in this study, are safe in terms of Ni concentration. Given its low concentration in the studied samples, the variations in Ni are considered an artefact of natural variations in Ni concentration, originating primarily from geo-genic source.

Other inorganic contaminants include Total Hardness (TH), Ca, and Mg contents, which have been taken from published literature (Table-1). The recommended values by the WHO (2011) and the acceptable limit set by BIS (2012) are also presented in Table-1. It can be seen that all these values are beyond these recommended values.

The isolated fungi were identified by both macroscopic and microscopic examinations, which included morphological features like shape, color, colony, diameter, etc. as well as microscopic features such as the size, shape, and color of fungal hyphae, spores, and other reproductive structures, in accordance with taxonomic placement. The texture, colony surface, color, and pigment at reverse (underside) that appeared in positive fungal growth on PDA medium were detected. A small portion of fungal growth was mixed with drops of lactophenyl cotton blue on a slide (Leck, 1999), then to be examined under low- and high-resolution microscopes for the presence of macroconidia, microconidia, spores, and hyphae.

According to microscopic characters, phenotypic identification of the fungi is based on morphological texture, color, and colony size, along with characteristics such as arrangement and separation of hyphae, spore formation, spore size and shape, patterns and branching frequency of conidiophores, etc. (Nagamani et al., 2006; Monoharachary et al., 2014; Swathi et al., 2014). All these characters were compared with standard manuals for phenotypic identification. Fig. 3 shows representative fungal species, identified in water samples while Table-2 presents the identified fungal species in the drinking and groundwater samples of our study area, also providing information on different health problems that can occur in the presence of these bacterial and fungal contaminants.

The health survey data comprised 363 households, each with 5-6 members in average, who formed the representative samples for the studied area. Prepared questionnaires concerned several common ailments such as diarrhea, tooth decay, skin rash, hair fall, joint pain, etc., all of which originated from consumption and use of contaminated water. The respondents were asked to answer these questionnaires, whose outcome is presented in Table-3 below. It can be seen from the survey results that the most common problem, faced by the residents of the area, was hair loss followed by skin rash, tooth decay, diarrhea, and joint pain.

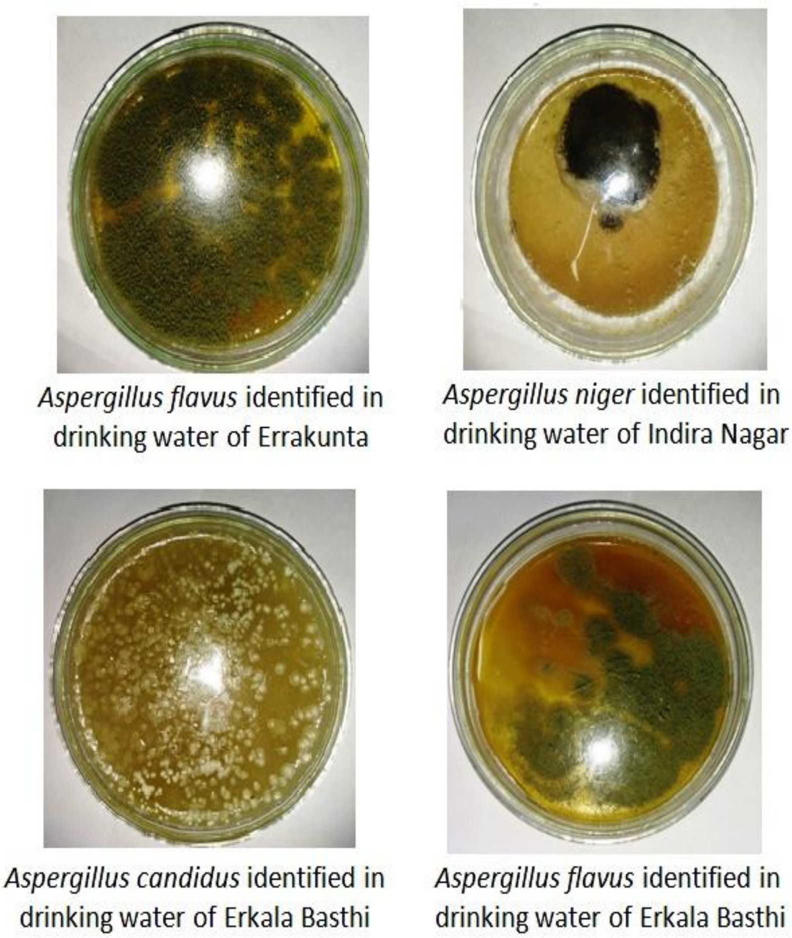

Fig. 3. Representative photographs of some fungi, identified in drinking water samples of the study area.

Table 2. Fungal colonies and reported bacterial species, identified as contaminants in drinking and groundwater samples from Nacharam along with their proven health effects

Type of bacterial and fungal colonies, identified as contaminants in drinking water and/or groundwater of Nacharam	Existing above safe limits in drinking water and/or groundwater samples	Health effects with reference
Actinomycetes (This study)	Groundwater from Indira Nagar and Erkala Basthi	Indirect causes of taste and odor problem (Jensen et al., 1994)
Aspergillus candidus (This study)	Drinking water from Indira Nagar, Erkala Basthi and groundwater from Indira Nagar	Respiratory disease, otomycosis, onychomycosis, brain granuloma (Ribeiro et al., 2005; Ahmadi et al., 2012).
Aspergillus flavus (This study)	Drinking water from Errakunta, Indira Nagar, Erkala Basthi and groundwater from Errakunta	Common clinical disorders comprise chronic granulomatous sinusitis, cutaneous disease affecting skin and/or hair as well as bone infection (Hedayati et al., 2007).
Aspergillus niger (This study and Shahnaaz et al., 2015)	Drinking water from Indira Nagar and Nacharam	Otomycosis, pulmonary aspergillosis (Georgiadou and Kontoyiannis, 2012).
Cladosporium sp. (This study and Shahnaaz et al., 2015)	Groundwater from Erkala Basthi, drinking water from HMT Nagar near Indira Nagar	Develops allergic reactions in susceptible individuals with one or more of the following symptoms: dry skin, sneezing, stuffy nose, coughing, itchy throat, eyes, and nose, watery eyes etc. (Sonigo et al., 2011)
Curvularia (This study)	Drinking water from Indira Nagar	*Curvularia* can cause severe fungal infections (mycoses) of the skin (Retrieved September 03, 2017 from http://www.wiseGEEK.com/what-is-curvularia.htm)
Drechslera (This study)	Groundwater from Erkala Basthi	*Drechslera* is a fungus which causes leaf infection, typically producing leaf spot. Leaf infections may occur as long as the weather remains moist and the temperatures are favorable (Smiley et al., 2005).
Fusarium (This study)	Drinking water from Indira Nagar	A number of infections are attributed to some species of *Fusarium* such as onychomycosis (nail infection), certain skin infections, bone and joint infections, pneumonia, etc. (Guarro and Gene, 1992).
Faecal coliform bacteria (Institute of Preventive Medicine, Hyderabad, cited by Garari, 2016)	Drinking water from Nacharam	Presence of faecal coliform bacteria indicates contamination of water with fecal waste and may contain other harmful or pathogenic organisms, like bacteria, viruses, or parasites. Drinking water, contaminated with these organisms, may upset the stomach, through diarrhea, skin rashes, etc. Some pathogens, such as E coli, hepatitis, and Salmonella, can have very severe health effects (Butler, 2005).

Table 3. Survey Results

Survey Area	No. of household surv-eyed	Waterborne common ailments reported by the respondents of the surveyed household					Remark
		Diarrhea	Tooth decay	Skin rash	Hair loss	Joint pain	
Indira Nagar	58	4	0	15	15	0	Skin rash & hair loss is high
%age of household affected in Indira Nagar		7	0	26	26	0	
Errakunta	127	8	18	10	61	0	Hair loss is very high, tooth decay is moderate
%age of household affected in Errakunta		6	14	8	48	0	
Ambedkar Nagar	16	0	0	0	7	0	Hair loss is high
%age of household affected in Ambedkar Nagar		0	0	0	27	0	
Erkala Basthi	162	8	12	11	58	14	Hair loss is very high
%age of household affected in Erkala Basthi		5	7	7	36	9	
Total	363	20	30	36	141	14	Hair loss is very high, skin rash is moderate
%age of Total		6	8	10	39	4	

In order to ascertain a meaningful inference of the survey results, we have already presented the results on water samples collected from the study area in Table-1 and Table-2. Table-1 also provides information on different health problems that can occur due to use of water, contaminated with excessive amount of major elements and heavy metal contents in the groundwater and surface water samples. As far as the health impacts from the presence of identified fungal and bacterial species are concerned, a brief account of each is also given (see Table-2).

A closer look at our survey results, presented in Table-3 which are examined in conjunction with the reported bacterial and fungal colonies identified as contaminants in drinking water samples (Table-2) as well as major and heavy metal contaminants in water samples (Table-1) from Nacharam with their proven health effects, reveal the following facts that are now established through this study without any ambiguity: Firstly, contamination of water bodies with pathogens during heavy rains and floods, which results in overflow of sewage drains, is a major problem of the study area. Secondly, it is quite a common phenomenon for untreated wastes from humans, animals, and birds to get mixed with drinking water. And finally, despite prohibition laws, secret dumping of industrial wastes continues at various scales. As there is no other common cause to be held responsible for the reported health problems in the study area, it appears that all ailments, reported by the citizens of the surveyed households, are waterborne, primarily originating from consumption and use of contaminated water. Accordingly, we further analyzed our survey results. As such, the percentage of households, corresponding to Indira Nagar, Errakunta, Ambedkar Nagar, and Erkala Basthi, which are having different health-related issues is depicted in separate pie charts (Fig. 4). Figure 4 also shows the pie chart that corresponds to the entire Nacharam area.

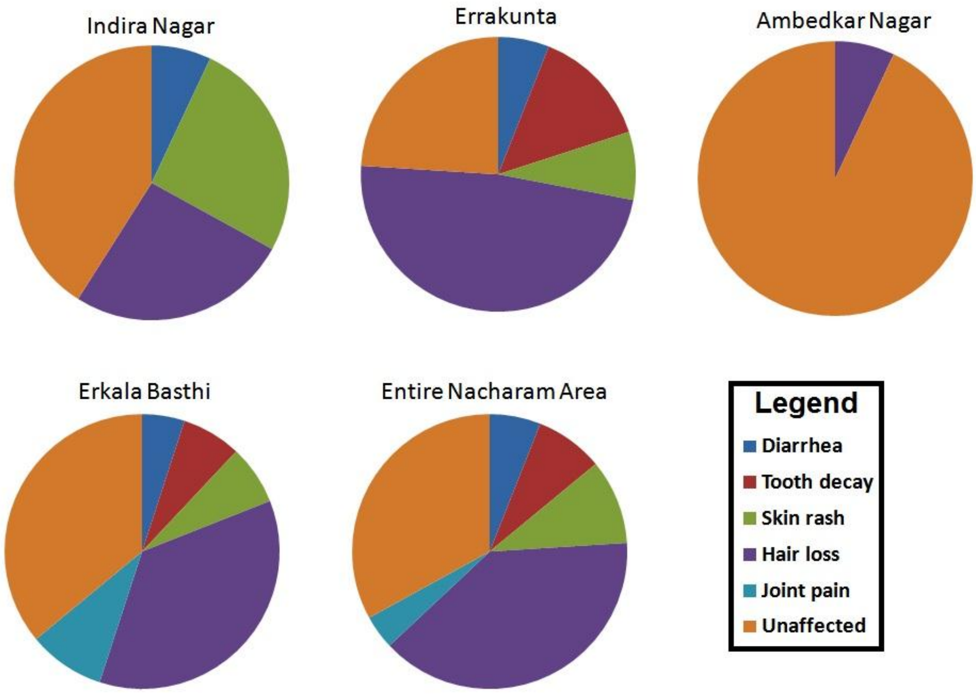

Fig. 4. Pie charts for the survey results

It can be understood from Fig. 4 that the percentage of households, unaffected by any kind of ailment is maximum (93%) in case of Ambedkar Nagar area; however, in case of Erkala Basthi, located within Ambedkar Nagar, it is low (36%). At first glance, this may seem surprising. Nonetheless, since Erkala Basthi is an area within Ambedkar Nagar in which the poor live and the houses are built in terribly filthy environments, we speculate that poor hygienic conditions are responsible for such results. This argument is further reinforced when considering the study conducted on the quality of drinking water of Ludhiana in Punjab (Sahota et al., 2014). These researchers documented high level of microbial contamination at specific sites of Ludhiana. According to them, the possible reason for high level of microbial contamination in these sites could be attributed to poor water storage conditions, distribution lines, untreated water, sewage, poor hygiene, crowded living conditions with inadequate sewage facilities, etc. Similar reasons may be true in case of Erkala Basthi area, as well. Therefore results from Ambedkar Nagar and Erkala Basthi cannot be considered unexpected. The percentage of households, unaffected by waterborne common diseases in Indira Nagar, is higher (41%) than that of Errakunta (24%) (Fig. 4). When entire Nacharam area is taken into consideration, this percentage gets close to 33% (Fig. 4). Of all the ailments, listed in Table-1 and 2, hair loss seems to be the major problem, reported by large number of residents (Table-3) of the study area. The percentage of affected households with hair loss problem in the four areas varies from 7% to 48% with an overall percentage of 39% for the entire area (Fig. 4), which forms the major concern of our discussion, as a result.

Reason for hair loss is a contentious issue without any general agreement about the main factors, causing it. Some scientists argue that the male hormone testosterone is the one to cause major hair loss (Kaufman et al., 2008; Alsantali and Shapiro, 2009; Kopera, 2015). Testosterone is closely connected with heredity, thus if a man has inherited the necessary genes, a little testosterone is formed into a derivative called dihydrotestosterone at some of the hair roots. Dihydrotestosterone miniaturizes the hair root and follicle, making new hair growth through it finer. The process is repeated again and again until baldness takes place. There is another group of scientists who focus their attention on blood flow. According to them, the main cause of hair loss is poor blood flow to the scalp, insufficient nutrients in the blood, and poor disposal of waste products through the lymphatic systems (Wester et al., 1984; Klemp et al., 1989). Loss of hair can also be due to excessive oil (sebum) in the scalp. Sebum clogs the pores of the scalp, stifling follicle growth (for more details on reasons of hair loss, see Paus, 2006). Thus the above three factors are the most common causes, considered by the scientists, for hair loss problem. However, we do not consider them to be feasible reasons for our respondents in the present survey. The reasons for such inference are validated by the following arguments:

(i) Testosterone is connected with heredity and the hair loss problem reported by our respondents during face-to face interviews confirms that the problem is not associated with such genetic inheritance.

(ii) Poor blood flow to the scalp cannot be the feasible reason for hair loss of our respondents, as there are other health problems such as discolored skin, swollen feet, feelings of fatigue and dizziness, cold hands and feet, throbbing limbs, lack of appetite, memory loss, etc., which are associated with poor blood flow. None of the respondents reported any of these problems.

(iii) Since the cause of excessive sebum in the scalp either can be hereditary or could have to do with individual's hormonal imbalance, we did not regard it a feasible cause for our respondents.

In order to evaluate the most plausible causes of hair loss in our study area's citizens, we explored the possibilities of other causes of hair loss also, including (a) emotional strains, stresses, and nervous disorders, (b) aging, (c) infections, (d) polluted environment, (e) use of hard water, (f) injury and impairment, and (g) use of drugs and/or radiation during treatment. Of all the causes listed here, only one possibility seems to be feasible for the residents of Nacharam area, i.e., continuous and prolonged use of hard water. There are active debates on hair loss problem vis-à-vis use of hard water. Although there is no strong evidence from medical professional in this direction to evaluate the real cause of hair fall, there are some studies, pointing to the fact that well-being of the hair can be affected through prolonged use of hard water (Guci Image, 2014). According to them hair can become brittle and frizzy, triggering scalp eczema, scalp calcification, etc., which is due to the presence of calcium and magnesium in hard water. Such build-up of unwanted substances in the scalp block hair follicles, thereby affecting healthy hair growth, and ultimately leading to hair miniaturization, the major health problem reported in this survey.

Other health issues, reported by the residents of our study area, included skin rash (10%), tooth decay (8%), diarrhea (6%), and joint pain (4%). As summarized in Table-1 and Table-2, there could be one or more sources in water for development of skin rash, which include faecal coliform bacteria and fungi such as *fusarium, aspergillus flavus, curvularia,* etc., along with heavy metal Cr(VI). Likewise, tooth decay may happenn either from excessive fluoride, lead, or both metals in water (Moss et al., 1999). In this context, it can be said that in a study conducted by Tripathi et al. (2000), whole blood samples of children from two highly industrialized cities of Mumbai and Hyderabad were compared, in terms of Pb levels. It was found that the mean lead level of blood in children from Hyderabad was higher [13.3 $\mu g(dl)^{-1}$] than those of Mumbai [8 $\mu g(dl)^{-1}$], indicating more health issues, related to lead toxicity. Focusing on faecal coliform bacteria in drinking water (Butler, 2005), one can see that these bacteria might be the most plausible sources to cause diarrhea among the inhabitants of the study area. The other reason may be increased intake of magnesium and sulfate through hard drinking water. In fact presence of high concentrations (~250 mg/l) of both magnesium and sulfate in hard water can have laxative effect (Sengupta, 2013). Finally, either the excess lead content (Table-1) or presence of fungi such as *fusarium, aspergillus flavus* (Table-2) or both in water samples may be responsible for joint pain in 4% of the residents of our study area.

CONCLUSION

Our study revealed that hair loss was the major health problem of the residents in the survey area, which has been interpreted to be due to excessive hardness of ground and surface water bodies. Presence of faecal coliform bacteria probably is responsible for producing skin rash and diarrhea, with other sources of skin rash including presence of fungi like *fusarium, aspergillus flavus* as well as heavy metal Cr(VI) in water. Tooth decay and joint pain could possibly be originated from excessive lead and fluoride contents, in addition to fungi such as *fusarium, aspergillus flavus,* etc. in water. With the exception of hair loss, the survey data suggested that the number of residents, affected by other waterborne health problems, was not very high. We therefore recommend that before the problem becomes a menace, general awareness about adverse effects of drinking and use of contaminated water needs to be provided to the residents of the area so that they get alert in future. In fact one of the key ideas of this survey was to educate the inhabitants during the face-to face interviews. Furthermore, the water, used by the residents of the survey area, should be periodically analyzed as a preventive measure against spread of microorganisms. Constant care should be paid to stop other anthropogenic sources such as dumping of waste materials, potentially harmful for water contamination.

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